A first analysis of the photovoltaic auction program in Germany

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***Abstract*— Tender schemes are increasingly used to determine financial support levels for electricity generation from renewable energy sources. Central for the success of such tenders is an understanding of realization rates and the program's procurement costs. However, the relatively long lead time between the auction and the planned commercial operation of the projects and the incomplete information about individual bids often limit such analysis. Moreover, an assessment of competition should complement the analysis of procurement costs as price reductions might be driven by other variables and even if currently observed prices are low, a decline in competition along the auctions may lead to higher prices in the future. In our contribution, we overcome the information constraints for the solar auction program in Germany. We quantify both realization rates and the level of competition to have a better understanding of the effect of auctions on the observed prices.**

***Index Terms*-- Auction, Competition, Germany, Photovoltaics, Project completion, Renewable energy.**

I. Introduction

Tender schemes have been increasingly used to determine financial support levels for electricity generation from renewable energy sources. Various auction programs have been planned to last several years and their prompt and precise evaluation is necessary if correcting measures in their design are to be taken. The evaluation of auctions for renewable energy sources often includes an assessment of effectiveness and procurement costs (also referred to as "cost effectiveness") [1], [2].

Effectiveness can be defined as the ability of a policy instrument to achieve a desired level of RES generation or capacity expansion [2], [3]. In this regard, past experiences with auctions have shown that, even in the presence of penalties for noncompliance, a successful bid placement i.e. allocation of the total tendered capacity, may not result in effective RES deployment [4]–[9]. Therefore, measuring effectiveness requires an ex-post indicator to assess whether awarded projects are built and brought into operation. Since policy targets on renewable energy penetration are usually expressed in terms of capacity and not generation expansion [3], project realization rates have become the leading indicator for the evaluation of policy target attainment [1]–[4], [10]–[15].

Procurement costs focus on resulting auction prices [1], [4], [16]–[18]. Note that neither costs nor prices are appropriate criteria to evaluate efficiency. While efficiency (often split into static and dynamic elements) is a central economic evaluation criterion, most of the current literature on auctions for renewable energies mentions it but does not quantitatively analyze it.

However, even an auction evaluation restricted to the analysis of effectiveness and procurement costs poses difficulties. Regarding the assessment of effectiveness, the limited information published about awarded bids constitutes an obstacle towards the identification of projects and their development status. Moreover, even with complete information about the awarded bids, the relatively long lead time between the auctions and the planned commercial operation of the projects delays the measurement of realization rates. As a result, studies often limit the analysis of realization rates to one or two auctions within the programs or even resort to other indicators for capacity deployment, e.g. awarded capacity [2], [5], [14], [19], [20] – which essentially ignores that realization rates are below (or at best equal to) one.

Procurement cost developments, while simple to assess, can be misleading when attributed to a particular market design. Price reductions can be the result of an efficient auction design, but they can also result from other factors, in particular technology cost reductions [1], [14], [21], [22]. They could even result from practices such as underbidding [21], [23] or winners curse scenarios [24], signaling the opposite of an optimal auction design.

Second, even if currently low procurement costs respond to the auction design, decreasing levels of competition may lead to higher future prices. In this context, we argue that contrasting auction prices with the level of competition could facilitate the evaluation of cost effectiveness. Since auctions can only result in efficient prices if they are competitive [2], [5], [15], [18], [21], finding appropriate levels of competition can provide important information to estimate future auctions' cost effectiveness.

In this study we analyze the German solar auction program. We take advantage of (i) the maturity of the program which accumulates a total of thirteen auctions, seven of which already reached financial closure i.e. the deadline for project commissioning has been met and (ii) the fact that the program is understudied. Recent literature on German auctions has focused on the wind onshore and offshore programs [23], [25]–[30] whereas the last academic study analyzing the PV auction program in Germany was published in 2015, when only two auctions had been held [31].

By merging various datasets on auction results, installed renewable energy units and payments for renewable energy generation, we overcome the information constraints regarding awarded bids and project completion times. Using this information, we (i) estimate realization rates and assess the program's effectiveness and (ii) estimate the degree of competition and analyze its effects on auction prices and the program's cost effectiveness. The paper is structured as follows: Section II describes the methodology and data used for the analysis. In section III, we present results about the program's effectiveness and cost-effectiveness. Section IV finally concludes, and some recommendations are highlighted to improve transparency in the disclosure of auction results.

II. METHODOLOGY

A. *The German solar auction program*

In 2015, following the European Commission guidelines favoring competitive bidding schemes to assign RES supports [32], Germany introduced a pilot scheme for solar energy auctions[1]. Since 2017, solar auctions are mandatory i.e. ground-mounted PV plants with a size of 100 kW and up to 10 MW can only obtain financial support if they participate and win in an auction. As depicted in Fig. 1, until completion of this study, a total of 13 solar auctions have been held and seven have reached financial closure. Auctions work on a pay-as-bid basis except for the second and third auction held in 2015. Bid capacity has always exceeded tendered capacity except in the first auction (AU1) when the amount tendered was excessively high (4 times more than usual levels).

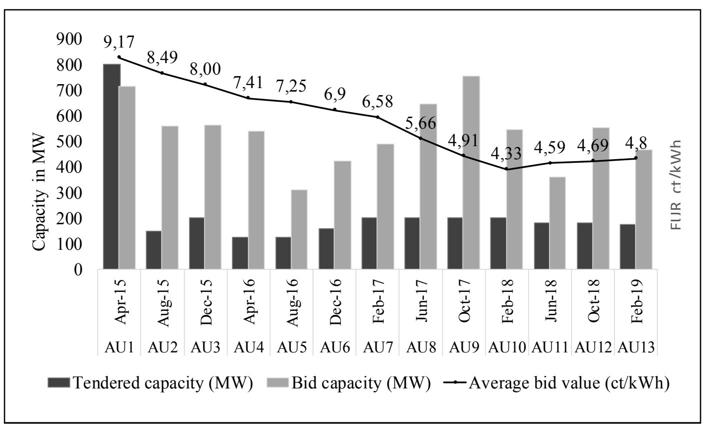

Figure 1. Solar auction results

Regarding prices, a strong decrease of more than 50% was observed from 2015 to 2018. While prices have slightly increased since then, they remain at low levels, resulting in a positive general opinion towards the solar program.

B. *Data*

In Germany, RES auctions are organized by the German Federal Network Agency (Bundesnetzagentur- BNetzA). After the auction is held, BNetzA publishes the auction results including a bid-ID[2], the number of projects comprised in each bid, the planned construction site and the name of the project developer but no information is given regarding the bid value or the project size. Additionally, when an auction reaches financial closure i.e. two years after the auction is held, BNetzA publishes the aggregated realization rate, however, (i) after the third auction the publication of realization rates has been delayed and (ii) BNetzA does not reveal information about the development status of single projects at the end of the 24-month construction period. This information must be retrieved using the RES Units Register (Anlagenregister) also published by BNetzA on a monthly basis. Based on the bid-ID, we matched the two data bases to identify the projects, i.e. for each project we find a unit-ID[3], the size in kW, the commissioning date and the final construction site. Projects not found in the RES Units Register are assumed to be cancelled or not finished. Table I summarizes the main descriptive statistics for each auction.

TABLE I. DESCRIPTIVE STATISTICS

Auction	**Awarded capacity [MW]**	**N° bids**	**N° projects**	**N° aggregated developers**	**Mean project size [MW]**	**SDev. project size [MW]**	**% projects with location change**
AU1	157	25	36	13	4.3	3,2	81%
AU2	159	33	42	17	4.1	2,9	81%
AU3	204	43	48	28	4.7	3,1	65%
AU4	128	21	32	13	4.3	3,5	72%
AU5	118	22	27	14	4.5	3,1	78%
AU6	163	27	43	12	3.8	3,0	77%
AU7	200	38	57	12	2.8	2,7	79%

C. *Realization rates*

We calculate the realization rate RR for each auction, as the sum of commissioned capacity over the awarded capacity using (1). Where t denotes the auction ($t=1,\ldots,13$), m is the number of completed projects in t ($m=1,\ldots,M$), C_m is the size in kW of commissioned project m and TC_t is the total awarded capacity in kW in t.

$$RR_t = \sum^M C_m / TC_t \qquad (1)$$

Final realization rates are calculated for the seven auctions that reached financial closure and partial RRs for the auctions AU8 to

[1] An overview of the German Energiewende can be found in [33]. Link to Working Paper and Video.

[2] The bid-ID is an 11-character code indicating the auction year, auction and placement among all received bids, e.g. FFA15-1/129 is the code for a winning bid from the first auction in 2015. In arrival order, this bid was the number 129 of 170 bids placed in that auction.

[3] The project or unit-ID is 33-digit code assigned to each RES commissioned unit.

AU13 i.e. for these auctions it holds that $m<M$ and the result is partial because commissioning deadlines have not been met.

D. Procurement costs

It is consensus in the literature that auctions can only deliver efficient prices if they are competitive [2], [5], [15], [18], [21]. Hence, finding appropriate levels of competition provides important information to make conclusions about the auction's ability to minimize procurement costs.

Based on the work of Bayer et al. [14], we assess competition using aggregated interest, agent frequency and market concentration as described in Table II**.** Using these three dimensions allows for the analysis of the program's demand while controlling for its quality, i.e. assess whether the demand in bids and capacity represents only few and powerful developers.

TABLE II. COMPETITION DIMENSIONS AND MEASURES

Dimension	Definition	Indicator	Evaluation
Aggregated interest	Interest to participate in the auction	Bid capacity / Tendered capacity	Low if ratio <=1
Agent frequency	Average bids per aggregated developer	Awarded bids / N° of agg. awarded developers (cumulative)	Evolution
Market concentration	Market share	Concentration ratio CR_3 *[program based]*	High if CR_3 >=60%
		Herfindahl Index HHI *[individual auction]*	Moderate if 0.15 < HHI <= 0.25 High if HHI > 0.25

Aggregated interest is calculated for each auction independently and measures the capacity of all bids submitted relative to the tendered capacity. Agent frequency is calculated for each auction *t* as the cumulative sum of bids until *t* relative to the cumulative sum of aggregated[4] awarded developers until *t*. i.e. this indicator measures the average bids won per developer and can help revealing the existence of multi-project or multi-auction bidders. For the market concentration dimension, we use two indicators: The Herfindahl-Hirschman Index (HHI), measured based on market shares within each auction and the concentration ratio (CR3), measured as the market share of the three largest developers for the accumulated program. In contrast to the agent frequency dimension, indicators for market concentration focus on the size and not on the number of bids won per developer.

III. RESULTS

A. Realizationn Rates

We calculate realization rates for the seven auctions that reached financial closure and partial RRs for auctions AU8 to AU13. As shown in Table III, our results fit the RRs published by BNetzA (the highest deviation amounts to 2% in AU3). These small deviations may result from changes made by developers after the commissioning deadline, that are not accounted in both data bases due to publication lag e.g. taking care of connection problems or defective units. The small deviations also demonstrate the appropriateness of our methodology for the estimation of final and partial RRs.

TABLE III. REALIZATION RATES

Auction	Auction date	Deadline	RR [BNetzA]	RR [Own estimation]	% completed projects
AU1	Apr-15	May-17	99%	99%	100%
AU2	Aug-15	Aug-17	90%	90%	83%
AU3	Dec-15	Dec-17	92%	94%	85%
AU4	Apr-16	Apr-18	100%	100%	100%
AU5	Aug-16	Aug-18	96%	96%	93%
AU6	Dec-16	Dec-18	99%	98%	98%
AU7	Feb-17	Feb-19	-	71%	88%
AU8	Jun-17	Jun-19	-	79%	86%
AU9	Oct-17	Oct-19	-	5%	19%
AU10	Feb-18	Feb-20	-	1%	3%
AU11	Jun-18		-	6%	7%
AU12	Oct-18		-	0%	0%
AU13	Feb-19		-	0%	0%

From AU1 to AU6, the program reaches extremely high realization rates with an average of 96%. In contrast, only 71% of the tendered capacity in AU7 was realized. However, this lower RR may result from a publication lag in the BNetzA register. Moreover, including AU7, the program still shows an outstanding average realization rate of 93 %. In addition, for 2015 and 2016, Germany reached its objective to increase installed capacities from ground-mounted PV by 400 MW p.a. [34, Para. §1], and it probably will do so in 2017. Therefore, the German solar auction program can be rated as deployment effective.

It is a vital question whether we are at a turning point in terms of realization rates. Starting with AU7, our data show that realization rates dropped below 80 %. By March 2019 the partial RRs show that only 20 % of AU9 projects and 3 % of AU10 projects have been commissioned, equivalent to 5% and 1% of capacity realization. However, there is not sufficient data to answer this question at this point: On the one hand, we may be facing a drop in realization rates – with important policy implications. On the other hand, the drop might also result from late/delayed publication of data by BNetzA, i.e. the projects may be completed/on their way to completion but not yet included in the publicly available data.

B. Procurement Costs

As depicted in Fig. 3, results for competition show an extensive interest to participate in the program. On average, the bid capacity is around three times higher than the amount tendered, and while the indicator decreased for auctions AU5 to AU7, interest on the program was still considerably high. Moreover, our estimation for

[4] We estimate the number of developers by aggregating winning bidders whose company location was registered under the same address.

auctions AU8 to AU13 shows comparably high levels of aggregated interest. Furthermore, the indicator for agent frequency shows that on average, developers win two bids per auction. i.e. the presence of multi-project or multi-auction bidders is not strong.

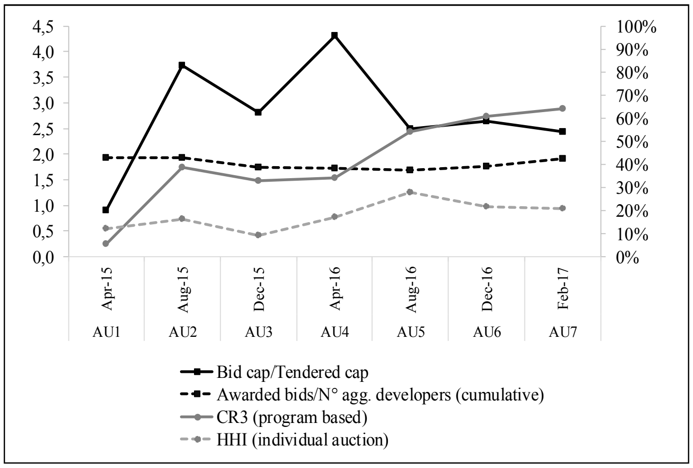

Figure 2. Indicators for competition

Finally, HHI and CR_3 show moderate levels of market concentration, with an average of 18 % and 42 % respectively. Further, we do not find a substantial difference between indicators for the individual auctions and the aggregated program. However, we want to point out that both results could be underestimated by the inclusion of AU7 because this auction has an under average realization rate i.e. due to publication lag there is a chance that 30% of the capacity, if belonging to developers with a high market share, will not be considered in the estimation of their market shares. Also, since our method for developer aggregation is not based on an in-depth analysis of the company's ownership structures, the possibility of further aggregation exists. Thus, our indicators could underestimate results for agent frequency and market concentration.

The pooled analysis for the three competition dimensions highlights the capacity of the German PV program to successfully attract solar project developers. Moreover, the low and moderate levels for agent frequency and market concentration speak for an appropriate auction design where (i) bigger and smaller developers have similar chances of winning bids and (ii) big developers do not dominate the market at this point. Together, these three results show that auction prices were formed in a competitive environment, where the auction design can be assumed to push bids towards marginal costs.

IV. CONCLUSIONS:

The German solar auction program has been effective in the deployment of solar generation capacities. Results for the first seven auctions indicate an average realization rate of 93 %. Targets for solar expansion pursued with the auctions were reached.

Furthermore, the high level of competition found along the program, together with high realization rates, suggests that prices reflect the true marginal costs of solar generation in Germany[5]. While low prices might be the result of steep technology cost reductions, the competitive auction design is responsible of pushing developers to incorporate those reductions into their bids. This can be considered a success of the implementation of auctions in the field of renewable deployment.

However, we highlight that these results apply exclusively for the first seven auctions. Preliminary estimations for successive auctions show a deterioration in realization rates. This decline could result from various factors, but it requires further data and additional analysis to quantify and distinguish between them. Nonetheless, we already point out that the implications could be severe if the reduction in realization rates were not the result of lagged publication of data.

In this context, we highlight that neither realization rates nor procurement cost reductions are static measures. They evolve over time depending on factors outside the specific program characteristics. Therefore, the evaluation of auction programs should be done periodically. In addition, and with this aim in mind, we urge the regulators to improve and facilitate the access to auction results, in particular, data on single bid values and ownership structures of project developers.

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